ArcView Spatial Analyst

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One way the term "crime hotspot" has been used is to describe an area of high criminal activity density. This paper will briefly examine the use of Spatial Analyst, an extension product to Environmental Systems Research Institute's (ESRI) desktop GIS package ArcView, to generate density surfaces and derive hotspots for examination of areas of high crime density.

The Spatial Analyst extension uses data sets compatible with ESRI's Arc/Info Grid package, and provides similar functionality for global, zonal, and neighborhood functions for continuous data surfaces. The extension also provides the ability to generate continuous data from discrete events, such as crime incident points, and to generate discrete objects (polygons, contour lines) from a continuous field.

Because Spatial Analyst is an extension to ArcView, all of that package's GIS functions, as well as its customizability and scriptability are available to the user. The base applications are flexible enough to suit the researcher, while programmable enough to create applications for use by end users.

Spatial Analyst provides the user with two algorithm choices for the generation of density surfaces, both of which are explained within the Spatial Analyst online documentation. The Simple algorithm allows the user to specify a search radius. A circle of this radius is drawn around the center of each grid cell, and the number of points contained within this circle is then divided by the area of the circle. The resulting number is assigned to that grid cell.

The Kernel function is a bit more complex. For each input point, a surface is generated with its peak centered over the point, and smoothly diminishing in all directions until it reaches zero at a user-defined radius. The value for each grid cell, then, is determined by adding the z-values of each circular surface where it intersects the cell center. This function is fully explained in B.W. Silverman's *Density Estimation for Statistics and Data Analysis* (1986).

With either of these algorithms, the user has control over the resolution of the output grid, the search radius to use in generating the surface, and the optional use of a scaling factor. The scale factor, a numeric attribute of each

input point, can be used for such things as weighting types of crimes, or indicating multiple incidents at a single location.

How one uses the density surface, once generated, is a little more flexible. One common technique is to simply display all grid cells above a certain value (the highest peaks of the surface), and class those peaks of the surface as the hotspots.

Another method is to have the Spatial Analyst generate contours for the surface, allowing the crime analyst to identify localized peaks of high density.

Figure 1 contains examples of both of these technique's; hotspots which represent the peaks of the surface are visible in red. Contours have also been drawn for the density surface, and two of the many localized peaks have been marked. The incident data used to generate the density surface (and its attendant contours) are also displayed.

How well the generated hotspots fit the data seems to vary; some areas with seemingly high incidences of crimes do not display as peaks, and vice versa. Overall, the hotspots tend to be collocated with the high-crime areas. Some experimentation with various parameters, including grid radius, grid cell size, and search radius may improve these characteristics.

ArcView, the host program for the Spatial Analyst extension, has a complex, object-oriented interface and metaphor. While much of its operation is intuitive, many aspects of ArcView's design require reading the accompanying manual and tutorial. Many users, particularly those without a background in GIS, may wish to purchase books on ArcView's use or take a training course.

Use of Spatial Analyst can be even more complex, especially if the user has no experience with raster based GIS applications. Fortunately, the creation of density grids is very simple, and accessible through the built-in interface. For the user interested in such classic raster GIS functions as arithmetic and logical combinations of grid themes (for instance, a multiplicative intersection of a hotspot grid with a grid containing demographic data) is also easily carried out with the built-in interface. However, any complex manipulation of data or automation of procedures will require programming in the Avenue language.

In the course of writing the Spatial Crime Analysis System (SCAS), the Department of Justice Criminal Division GIS Staff developed a number of functions to simply the creation of hotspots with Spatial Analyst. Perhaps the most significant of these is the hotspot tolerance slider. This interactive tool allows the analyst to change the vertical level at which hotspots are clipped from the top of the density surface, by percentile. **Figure 2** contains an

example of the use of this slider. These hotspot functions have been folded into an ArcView extension. The extension, which requires Spatial Analyst and the run-time files of ESRI's ArcView Dialog Designer extension, provides interface buttons to help the user with such tasks as generating density surfaces, finding hotspots, finding incident points that fall within hotspots, and so forth. The scripts that make up the extension also provide programmers with the basic framework necessary for further extending ArcView for use in hotspot generation and analysis. The functionality within this extension is currently in use in the Montgomery County, Maryland Police Department by crime analysts.

The Department of Justice Hotspot Extension is available free of charge and will be available from the Criminal Division GIS Staff's home page.

The ArcView/Spatial Analyst combination provides a strong set of GIS and data access tools for working with myriad data. Support for data import and export, statistical analysis (coded internally or accessed through external software and dynamic link libraries), and the ability to automate processes and log results all help add up to a useful stand-alone package.

ArcView natively uses an open standard file format, the shapefile to store data. C-language functions are publicly available for reading and writing shapefiles. ArcView's shapefile format is based on the industry-standard dBASE file format (.DBF). Spatial Analyst stores its raster coverages in ESRI's grid coverage format. The Spatial Analyst distribution CD-ROM includes a C-language library and header with routines for reading and writing grid coverages.

In addition, ArcView is also able to import data from several common formats, including Vector Product Format (.VPF), MapInfo Exchange Format (.MIF), CAD Export Format (.DXF), and ESRI's own Export format (.E00). Support ESRI's arc-node coverage format is also built-in. ESRI networks may be read when the ArcView Network Analyst is installed.

ArcView also supports the Open Data Base Connectivity (ODBC) data standard. With ODBC drivers available for most commercial database products, as well as many spreadsheets and text file formats, it becomes possible to store point incident tables externally to ArcView and work directly with the data from that external source in the creation of density surfaces.

ArcView, and by extension Spatial Analyst, are well suited to extensibility for statistical operations. The included Avenue scripting language can be used for quite a bit of numerical processing. Avenue also provides the

ability to make calls to Dynamic Link Libraries (DLLs) which might contain code to perform such operations as k-means clustering. One would be able to pass data to such a DLL and then be passed back a result. As another means of using external software, data input and output is suitably available, and it is a relatively simple matter to automate the process of writing out a data file in a format necessary for a given processing (statistical or otherwise) package and, if the external package allows it, run operations on the data file from a command line.

ArcView GIS is an object-oriented system which is highly customizable. The package comes with an object-oriented scripting language, Avenue, which provides a high level of control over virtually all aspects of the GIS. Further, the interface of the software can be easily modified through either direct manipulation or programmatic control. In fact, virtually all of the functions packaged into the default interface are simply Avenue scripts which may be modified or replaced by a programmer. The software interface may be easily enhanced as well. ArcView, as of version 3.0a, provides a graphical editor, the Dialog Designer extension, for creating new dialog boxes and controlling all of their events through the Avenue language.

It should be noted that Avenue is a complex language, embodying many object-oriented concepts, and providing access to a large and complicated object model. While very well documented, the language can be difficult to learn, particularly for those people without experience in the object-oriented paradigm. Again, third-party books are available, as are training courses.

On the Win32 (Windows 95 and Windows NT) platform, one may use other programming languages (e.g. Visual Basic, Delphi, and Visual C++) to create interfaces for ArcView. The advantage to doing so is the extreme flexibility one has, particularly for the use of such exotic controls as treeview and calendar widgets. Such external interfaces have the disadvantages of being relatively slow in their communication with ArcView and not being portable to other operating systems on which ArcView runs. In addition, one can not simply replace Avenue with, say, Visual Basic in hope of not having to learn the former. Avenue is still required to allow ArcView to exchange data with the external interface, as well as to make use of any data generated by that external program. The DOJ Hotspot Extension's tolerance slider concept was originally implemented in Visual Basic, before the Dialog Designer extension was made available. It has since been re-written solely in Avenue and should run on any platform for which custom dialog boxes are supported.

All Spatial Analyst functions may be controlled or automated with Avenue. The raster data model is well integrated into the ArcView object model, and functions may be easily programmed by someone with Avenue and

raster GIS experience. The DOJ Hotspot Extension provides some examples of using Avenue to create and manipulate grids.

Overall, the ArcView and Spatial Analyst combination is quite powerful. ArcView, with its customizability and extensibility is a powerful platform, and Spatial Analyst provides at least one way of assessing crime incident hotspots. With that said, though, it should be noted that the Spatial Analyst extension is fairly expensive (more so than ArcView itself). Currently, the Department of Justice Criminal Division GIS Staff has, for the most part, just used the Spatial Analyst extension to generate density grids and convert grids to polygons. However, with the power and flexibility within the extension, one might reasonably expect to do more and varied sorts of analyses with the tool.

Appendix A

   The following maps were created using the DOJ Hotspot Extension to drive ArcView and Spatial Analyst in the creation of hotspots.

   Figure 1 is an example of both hotspots and contours, as generated by ArcView and Spatial Analyst.

   Figure 2 details the operation of the Hotspot Extension tolerance slider.

   Figures 3-6 are maps as requested by the study organizer. The data used was that provided by NIJ for this study. Spatial joins, along with ordinary attribute queries were used to isolate the desired data for each given map.

   The final image, **Figure 7**, shows a set of 12 density surfaces by month. For these surfaces, a few simple Avenue scripts were developed to quickly extract database records based on incident date, save them to individual files, for which density surfaces were then calculated. These images provide an interesting insight into the movement of crime incidents throughout the course of the year.

Bibliography

Silverman, B.W. Density Estimation for Statistics and Data Analysis. New York: Chapman and Hall, 1986.